

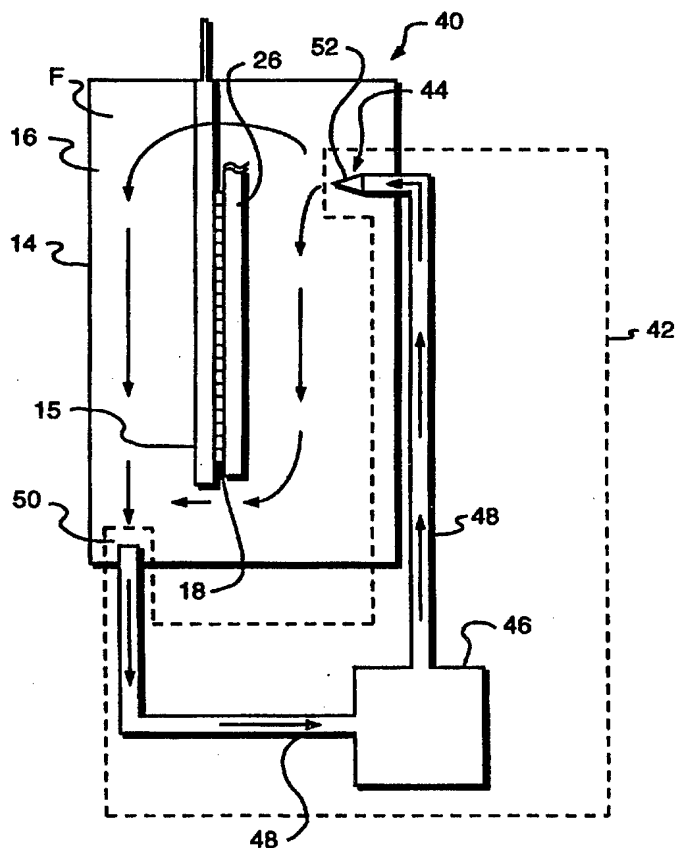


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(54) Title: UNIFORM ELECTROPLATING OF PRINTED CIRCUIT BOARDS**(57) Abstract**

A method and apparatus for the uniform electroplating of printed circuit boards is described. In one embodiment of the present invention, selected areas of the electroactive surface of the anode (15) or cathode electrode (26) are covered with a mask (18), whereby to establish substantially uniform electroplating ion transfer over the target areas of the target cathode (26).



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1 UNIFORM ELECTROPLATING OF PRINTED CIRCUIT BOARDS

2

3 This invention relates to electroplating or electro-
4 deposition of metal on a target. The invention has
5 particular utility in connection with electro-deposition
6 of metal onto printed circuit boards or panels and will be
7 described in connection with such utility, although other
8 utilities are contemplated.

9 Electroplating is an established process of producing
10 a metallic coating on a surface. Such coatings may
11 perform a protective function to prevent corrosion of the
12 metal on which they are deposited, e.g., plating with zinc
13 or tin (electro-galvanizing); or a decorative function,
14 e.g., gold or silver plating; or both functions, e.g.,
15 chromium plating.

16 The principal of electroplating is that the coating
17 metal is deposited from an electrolyte, typically an
18 aqueous acid or alkaline solution, onto a target substrate
19 or panel. The latter forms the cathode (negative
20 electrode) while a plate of the metal to be deposited
21 serves as the anode (positive electrode). Alternatively,
22 the anode may be made of an electrochemically inert (that
23 is, not subject to decomposition during electroplating)
24 metal and the plating metal may be deposited onto the
25 cathode solely from the electrolytic solution.

26 Usually, the cathode is coated with an industry
27 standard resist material to prevent plating of those areas
28 of the cathode covered with the resist. After plating of
29 the cathode, the resist pattern is removed, thereby
30 leaving unplated the areas of the cathode that had been
31 covered with the resist. As will be appreciated, such
32 conventional resist patterns are incapable of solving the
33 problems with which the present invention is concerned.

34 During a standard electroplating process, the
35 periphery of the printed circuit board, i.e., the portions
36 of the printed circuit board adjacent its outer edges,

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1 tends to be at a higher current density than the center of
2 the printed circuit board. Hence, metal deposits more
3 rapidly adjacent the periphery of the printed circuit
4 board than at the center. The result of this is that by
5 the time the metal has deposited at the center of the
6 circuit board to form a desired thickness, the metal
7 deposited adjacent the periphery is at a thickness much
8 greater than the thickness at the center. As a result,
9 the width of depositing metal lines may grow laterally,
10 and the resulting plated lines near the periphery may
11 develop a cross sectional configuration resembling a
12 mushroom.

13 In U.S. Patent No. 4,828,654, it is reported that by
14 spacing the cathode a relatively large distance from the
15 anode, and by making the effective size of the panel to be
16 plated, i.e. the cathode, larger in size than the anode,
17 there is more uniform distribution of the electroplating
18 field. The more uniformly distributed field causes the
19 metallic ions to be electrolytically deposited at a more
20 uniform rate over the articles in the panel. This prior
21 art arrangement reportedly avoids undesirable uneven
22 plating build-up on the articles at those areas where
23 there is a concentration of the electroplating field. It
24 is also reported that field concentrations occur when the
25 size of the article is smaller than the size of the anode,
26 and results in the edges of the article experiencing a
27 substantially greater build up of metallic ions than the
28 center area of the article. Making the effective size of
29 the cathode (the article to be plated) greater than the
30 size of the anode and spacing the anode a relatively large
31 distance from the cathode, operates to discourage the
32 formation of areas of concentration in the electroplating
33 field and encourages the ion transfer to become more
34 uniform over the entire area of the cathode.

35 U.S. Patent No. 4,828,654 teaches an anode used in
36 electroplating formed by a plurality of individual anode

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1 segments which can be selectively energized to establish
2 an effective anode size that relates to the size of the
3 article to be electroplated, thereby establishing an
4 electrical field of more uniform characteristics to
5 transfer ions from the anode to the articles at a more
6 uniform deposition rate over the whole surface of the
7 article. By adjusting the effective size of the anode to
8 correspond and relate to the size of the article, the non-
9 uniform deposition rates associated with concentrated
10 localized field reportedly are avoided, and the physical
11 size of the electroplating apparatus can be reduced.

12 U.S. Patent No. 4,933,061 teaches an electroplating
13 apparatus for electroplating a plurality of items. The
14 patented apparatus includes a tank having a bottom wall
15 and side walls, adapted to hold a predetermined quantity
16 of electrolytic plating solution. A sparger system at the
17 bottom of the tank directs the electrolytic plating
18 solution in an upward direction. A cathode rack supports
19 the items to be electroplated and extends intermediate to
20 the anode plates and upwardly from the sparger system.
21 Strategically placed openings in the anodes and an anode
22 screen in conjunction with the sparger system reportedly
23 act to reduce the plating thickness variance over the
24 rack.

25 In U.S. Patent No. 5,017,275, there is disclosed an
26 anode structure comprising a resilient anode sheet having
27 an active anode surface, and a support sub-structure for
28 the anode sheet. The anode sub-structure has a pre-
29 determined configuration. By flexing the anode sheet onto
30 the anode sub-structure, so that the anode sheet conforms
31 to the configuration of the anode sub-structure, there
32 reportedly is provided an adequate electrical junction for
33 substantially uniform current distribution.

34 A collection of the known variables which affect the
35 electroplating process have been set out in detail in the
36 HANDBOOK OF PRINTED CIRCUIT MANUFACTURING by Raymond H.

1 Clark (1985). Therein it is reported that the factors
2 which effect the electroplating process include:

- 3 1. plating pattern geography;
- 4 2. panel thickness and size of plated through holes;
- 5 3. panel boarders;
- 6 4. plating rack;
- 7 5. bath chemistry, e.g., concentration of metals
8 and acids, concentration of organic leveling and
9 brightening agents, concentration of contaminants;
- 10 6. bath temperature;
- 11 7. anode-cathode spacing;
- 12 8. anode current density;
- 13 9. anode depletion;
- 14 10. plating bath agitation;
- 15 11. cathode agitation;
- 16 12. rectifier consideration; and
- 17 13. the skill and experience of the plater.

18 The present invention provides an improved
19 electroplating system which overcomes the aforesaid and
20 other problems of the prior art which have resulted in
21 less than uniform electroplating and metallic deposition,
22 and in so doing provides substantially uniform
23 distribution of the deposited metal, from item to item in
24 an electroplating process.

25 In accordance with the present invention, a system for
26 electroplating comprises a receptacle for holding a bath
27 of electroplating solution. An electrically conducting
28 anode electrode is positioned within the receptacle in
29 contact with the bath. In one preferred embodiment, the
30 anode is covered at least in part with one or more
31 electrically non-conductive masks which operate to direct
32 the electric current as it travels through the
33 electroplating solution to distribute over the cross-
34 sectional surface area of a conductive substrate immersed
35 in the electroplating receptacle at a location spaced
36 apart from the anode to establish substantially uniform

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1 electroplating ion transfer over the surface of the
2 substrate. The mask or masks may be in direct contact
3 with the anode, or in close proximity thereto. Completing
4 the system are means for electrically energizing the anode
5 and completing the circuit to the target/cathode.

6 The overall size of the anode, and the size and shape
7 of the mask or masks, mask openings, number of openings,
8 and location of openings in the non-conductive mask are
9 all selected with reference to the size, target
10 configuration and aspect ratio (anode-to-target) of the
11 article to be electroplated. The distance separating the
12 masked anode from the target panel substrate also is
13 adjusted to promote uniform targeting of the
14 electroplating current.

15 The present invention also provides a method of
16 electroplating an article with a generally uniform
17 thickness coating. In one preferred embodiment, this
18 method comprises covering the anode electrode at least in
19 part with one or more electrically non-conductive masks
20 having a pattern of openings of predetermined
21 configuration relative to the target cathode whereby to
22 result in substantially uniform deposition over the target
23 during electroplating.

24 Further features and advantages of the present
25 invention will be apparent from the following detailed
26 description of the invention taken in conjunction with the
27 drawings, wherein like numerals depict like parts, and
28 wherein:

29 Figure 1 is a perspective view of an electroplating
30 apparatus embodying the present invention;

31 Figure 2 is a side view of portions of the
32 electroplating system of Figure 1; and

33 Figure 3 is a view similar to 2, and illustrating an
34 alternative form of electroplating system made in
35 accordance with the subject invention;

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1 Figure 4 is a side view of portions of another
2 preferred embodiment of an apparatus embodying the present
3 invention;

4 Figure 5 is a side view of portions of a variant of
5 the embodiment of Figure 4;

6 Figure 6 is a side view of portions of a further
7 variation of the embodiment of Figure 4; and

8 Figure 7 is a partial side-elevational view of an
9 alternative anode construction for use in the embodiments
10 of Figures 4-6.

11 Referring to Figures 1 and 2, one embodiment 10 of an
12 electroplating system according to the present invention
13 is illustrated. System 10 includes an outer housing 12
14 which is preferably formed of an electrically insulating
15 and corrosion-resistant material such as plastic. The
16 housing 12 includes means in the form of a downward
17 extending receptacle 14 for holding a bath of an
18 electroplating solution 16. By way of example, for
19 electroplating copper, bath 16 may comprise a copper
20 sulfate solution commonly referred to as "acid copper".
21 The plastic material of the housing 12 and receptacle 14
22 resists the toxic and corrosive effects of the bath 16.

23 The electroplating system 10 includes an anode
24 electrode 15 which preferably is covered at least in part
25 with a non-conductive mask 18 (Figure 2), which will be
26 described in detail below. Mask 18 may be coated directly
27 on the electro-active surface of anode electrode 15 or may
28 comprise a separate element which may be fixed to or
29 suspended in close proximity to the electro-active surface
30 of electrode 15. The anode electrode 15 and mask 18 are
31 suspended from an upper support member 20 which is
32 preferably formed of plastic to resist the corrosive
33 effects of the bath 16 and to provide electrical
34 insulation. The anode electrode 15 and mask 18 are held
35 suspended from the support member 20 by fasteners such as
36 non-corrosive titanium machine screw 22.

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1 The article to be plated typically comprises a printed
2 circuit board 26 which becomes the electrical cathode of
3 the electroplating system during electroplating. The
4 printed circuit board 26, which may be covered with an
5 industry standard resist material (not shown), is
6 suspended in the bath by a clamp 28 which includes a
7 thumbscrew 30 or other similar fastening device for
8 attaching and suspending or supporting the article to be
9 electroplated in the bath. Clamp 28 in turn is
10 mechanically connected to an electrically insulating
11 support member 34. A handle 36 extends above the support
12 member to allow the printed circuit board to be inserted
13 into and removed from the bath 16 at the start and end of
14 the electroplating process.

15 Completing the system are electrical conductors 29 and
16 32 for electrically connecting the anode electrode 15 and
17 cathode target 26 to a direct current or quasi direct
18 current electrical energy source 38.

19 A feature and advantage of the present invention is
20 the ability to substantially and uniformly electroplate
21 the conductor paths, lands and holes of a target printed
22 circuit board. Preferably, this is accomplished by
23 covering selected areas of the electro-active surface of a
24 solid anode 15 with a non-conductive mask 18 which directs
25 the electric current through the electroplating solution
26 so that the metal will be deposited onto the target
27 cathode in a controlled (that is, in a substantially
28 uniform) manner. The overall size of the anode, and the
29 size and shape of the openings, number of openings, and
30 location of the openings in the non-conductive mask are
31 selected with reference to the size and geometry of the
32 target article to be electroplated, with the result that
33 field concentrations at any location on the target article
34 are avoided, thereby achieving a relatively uniform layer
35 of electroplated material.

36 Typically, the mask generally will have openings which

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1 are substantially the negative of the target article.
2 However, in order to compensate for uneven plating buildup
3 on the target panel periphery, the mask openings
4 corresponding to peripheral areas of the target board
5 preferably should be made relatively smaller than
6 corresponding deposition areas on edges of the target
7 board, while the mask openings corresponding to center
8 areas of the target board preferably should be made
9 relatively larger than the corresponding deposition areas
10 on center areas of the target board. Mask size and shape
11 may be empirically determined using the above criteria.
12 The mask may be applied directly to the anode electro-
13 active surface, for example, by coating, or the mask may
14 comprise a separate element which may be fixed directly to
15 or held in close proximity to the anode electro-active
16 surface, thereby allowing various selected exposed
17 portions of the anode to serve as a source of field
18 concentration for the electroplating process.

19 The distance between the masked anode and the target
20 printed circuit board should be limited to a relatively
21 short distance, typically 2 to 3.5 inches at normal
22 plating potentials, so that bulk transfer through the
23 electroplating bath does not defeat the masking effect.

24 Certain changes may be made in the above constructions
25 without departing from the spirit and scope of the
26 invention. For example, as shown in Figure 3, it also is
27 possible to achieve uniform deposition by covering the
28 cathode with one or more non-conductive apertured masks.
29 In such case, the mask or masks should be spaced a short
30 distance, e.g. 1.75 to 3 inches from the cathode.
31 Locating the mask less than 1.75 inches or more than 3
32 inches from the cathode is not advised and may not achieve
33 uniform deposition.

34 Other modifications are also possible. For example,
35 as shown in Figure 4, in another preferred embodiment 40
36 of the present invention similar to that shown in Figures

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1 1-2, the anode 15 is placed in direct contact with mask 18
2 which is placed in direct contact with cathode 26.
3 Embodiment 40 also includes electrolyte circulation means
4 42 (shown in dashed lines) which permits controlled
5 circulation or flow F of electrolyte fluid 16 in bath
6 receptacle 14. Circulation means 42 comprises at least
7 one conventional nozzle means 44 connected to a
8 conventional filtered pump 46 which pumps fluid 16 from
9 bath 14 through pipe means 48 (via opening 50 in
10 receptacle 14) to nozzle 44, and thence, back into
11 receptacle 14. Preferably, nozzle means 44 comprises a
12 conventional shuttered aperture 52 for controllably
13 adjusting direction and magnitude of fluid flow from
14 nozzle 44. Advantageously, by appropriately adjusting
15 direction and velocity of the flow of fluid in bath 14,
16 the uniformity and speed of deposition of electroplating
17 material upon cathode 26 may be increased.

18 Figure 5 shows a variation 60 of the embodiment 40 of
19 Figure 4, in which variation 60 circulating means 42
20 comprises a plurality of nozzle means 44A . . . 44J
21 configured into two oppositely facing banks 62A, 62B of
22 nozzles on opposite sides of board 26. In this embodiment
23 60, the nozzles 44A . . . 44J are connected to a common
24 combination pressure manifold and circulatory pump 46.
25 Of course, each of the nozzles 44A . . . 44J or any number
26 of them may be connected to independent pumps and/or
27 pressure manifolds (not shown), without departing from the
28 present invention. Additionally, although only two banks
29 of five nozzles each are shown in Figure 5, it will be
30 appreciated that the number and configuration of nozzles
31 may be varied without departing from this embodiment 60 of
32 the present invention.

33 Various other modifications are also possible without
34 departing from the present invention. For example, the
35 nozzles 44A . . . 44J of embodiment 60 of Figure 5 may
36 comprise respective conventional shuttered-apertures.

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1 Additionally, as shown in Figure 6, the embodiments shown
2 in Figures 4 and 5 may comprise conventional controllable
3 electromotive means 64A . . . L connected to circulation
4 means 42 to permit the nozzles to move within bath 14.
5 Preferably, electromotive means 64A . . . L are controlled
6 via conventional programmable controller device 66 to move
7 the nozzles according to a predetermined pattern to
8 improve deposition of electroplating material upon cathode
9 26 by providing appropriate flow F of electrolyte fluid in
10 the bath.

11 Also alternatively, the embodiments shown in Figures
12 4-6 may comprise an alternative anode 15A shown in Figure
13 7. Anode 15A (which preferably is made of an
14 electrochemically inert material) may be used by itself
15 (i.e., without necessitating use of a mask) to accomplish
16 substantially uniform electroplate ion transfer onto the
17 target cathode. Preferably, anode 15A comprises a
18 metallic, fine wire mesh grid 74 having a plurality of
19 relatively small openings (representatively referred to by
20 numeral 72). The dimensions of the openings 72 of grid
21 anode 15A are empirically determined so as to permit
22 substantially uniform electroplate ion transfer onto
23 cathode 26. Preferably, when alternative anode 15A is
24 substituted into the embodiments of Figures 4-6, the anode
25 15A and cathode 26 are separated from each other by a
26 distance much smaller than 2 to 3.5 inches; preferably,
27 this distance is made such that the anode and cathode
28 almost contact each other. Alternatively, anode 15A may
29 be placed in direct contact with industry standard plating
30 resist on cathode 26.

31 Additionally, the industry standard plating resist
32 pattern usually placed on cathode 26 prior to the
33 electroplating process may be adjusted using computer
34 simulation techniques so as to aid the mask 18 and/or
35 anode 15A in establishing uniform electroplate ion
36 transfer according to the present invention.

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1 Other modifications may also be possible. It is
2 accordingly intended that all matter contained in the
3 above description or shown in the accompanying drawings
4 shall be interpreted as illustrative and not in a limiting
5 sense.

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CLAIMS

- 1
2
- 3 1. In an apparatus for electroplating a target
4 cathode, said apparatus including an anode electrode
5 having an electroactive surface in contact with
6 electrolytic fluid of an electroplating bath, the
7 improvement which comprises at least one electrically non-
8 conductive apertured mask in direct contact with and
9 covering said cathode at least in part whereby to direct
10 electric current through the electroplating solution in a
11 controlled manner onto the target cathode, said anode
12 being placed in direct contact with said mask (26) on said
13 cathode, and means (46) for controllably circulating said
14 fluid of said bath.
- 15 2. In an apparatus according to claim 1, the
16 improvement characterized by one or more of the following
17 features:
- 18 (a) said circulating means comprises at least
19 one nozzle means (44) for directing flow of said
20 circulating fluid in said bath;
- 21 (b) said cathode is interposed between banks of
22 facing nozzle means (44A . . .) for directing flow of said
23 circulating fluid in said bath;
- 24 (c) said circulating means comprises at least
25 one nozzle means (44A . . .) having adjustable shutter
26 means for changeably directing flow of said circulating
27 fluid in said bath;
- 28 (d) said at least one mask (15A) comprises a
29 plurality of openings (72) which are adjusted to establish
30 substantially uniform electroplate ion transfer onto the
31 target cathode;
- 32 (e) said cathode is interposed between two banks
33 of oppositely facing nozzle means (44A . . .) having
34 adjustable shutter means for changeably directing flow of
35 said circulating fluid in said bath; and wherein said
36 circulation means preferably comprises at least one nozzle

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1 means and electromotive means (64A . . .) for controllably
2 moving said nozzle means;

3 (f) said circulation means comprises a plurality
4 of nozzles connected to a combination pump (64) and
5 manifold for circulating said fluid of said bath, and
6 wherein at least one additional mask preferably is
7 interposed between said anode and said at least one mask
8 of said cathode, said circulation means preferably
9 comprises controllable electromotive means (64A . . .) for
10 controllably moving said nozzle means, and said nozzle
11 means (44A . . .) preferably has shutter means for
12 changeably directing flow of said circulating fluid in
13 said bath; and

14 (g) said cathode comprises a conventional resist
15 pattern disposed thereon, which pattern is adjusted to aid
16 said at least one mask in establishing substantially
17 uniform electroplate ion transfer to said cathode.

18 3. In an apparatus for electroplating a target
19 cathode, said apparatus including an anode electrode
20 having an electroactive surface in contact with
21 electrolytic fluid of an electroplating bath, the
22 improvement which comprises said anode being closely
23 spaced from said cathode, said anode including a wire mesh
24 (74) defining a plurality of openings (72) which are
25 dimensioned to permit substantially uniform electroplate
26 ion transfer onto said cathode, and means (46) for
27 controllably circulating said fluid of said bath.

28 4. In an apparatus according to claim 3, the
29 improvement characterized by one or more of the following
30 features:

31 (a) said mesh (74) has a grid-like
32 configuration;

33 (b) said circulating means comprises at least
34 one nozzle means (44 . . .) and electromotive means for
35 controllably moving said nozzle means;

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1 (c) said circulating means preferably further
2 comprises a programmable controller device (46) for
3 permitting predetermined motion of said nozzle means; and

4 (d) said cathode comprises a conventional resist
5 pattern disposed thereon, which pattern is adjusted to aid
6 in establishing substantially uniform electroplate ion
7 transfer to said cathode.

8 5. In a process for electroplating a target cathode
9 using an apparatus including an anode electrode having an
10 electroactive surface in contact with electrolytic fluid
11 of an electroplating bath, the improvement which comprises
12 placing at least one electrically non-conductive apertured
13 mask in direct contact with and covering said cathode at
14 least in part whereby to direct electric current through
15 the electroplating solution in a controlled manner onto
16 the cathode, placing said anode in direct contact with
17 said mask on said cathode, and controllably circulating
18 said fluid of said bath so as to permit substantially
19 uniform electroplating ion transfer onto said cathode.

20 6. In a process for electroplating according to
21 claim 5, the improvement characterized by one or more of
22 the following features:

23 (a) said fluid circulation is accomplished, at
24 least partially, by directing flow of said fluid through
25 at least one nozzle means, preferably by moving said
26 nozzle means according to a predetermined pattern;

27 (b) said fluid circulation is accomplished, at
28 least partially, by directing flow of said fluid through
29 at a plurality of nozzle means, preferably by moving said
30 nozzle means according to a predetermined pattern.

31 7. In a process for electroplating a target cathode
32 using an apparatus including an anode electrode having an
33 electroactive surface in contact with electrolytic fluid
34 of an electroplating bath, the improvement which comprises
35 forming said anode so as to include a wire mesh defining a
36 plurality of openings which are dimensioned to permit

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1 substantially uniform electroplating ion transfer onto
2 said cathode, placing said anode in close proximity to
3 said cathode, and controllably circulating said fluid in
4 said bath.

5 8. In a process according to claim 7, the
6 improvement characterized by one or more of the following
7 features:

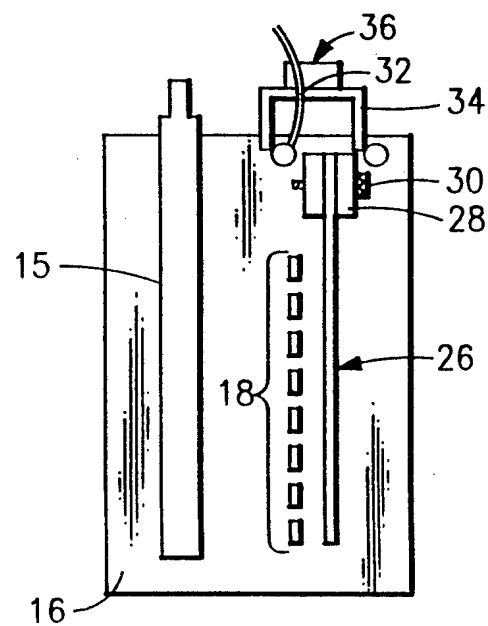
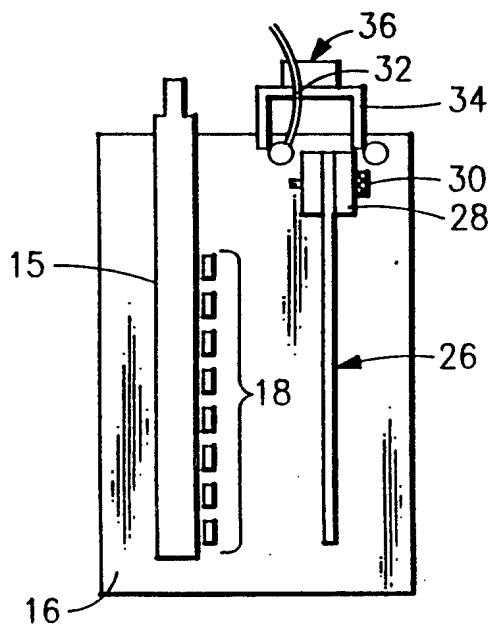
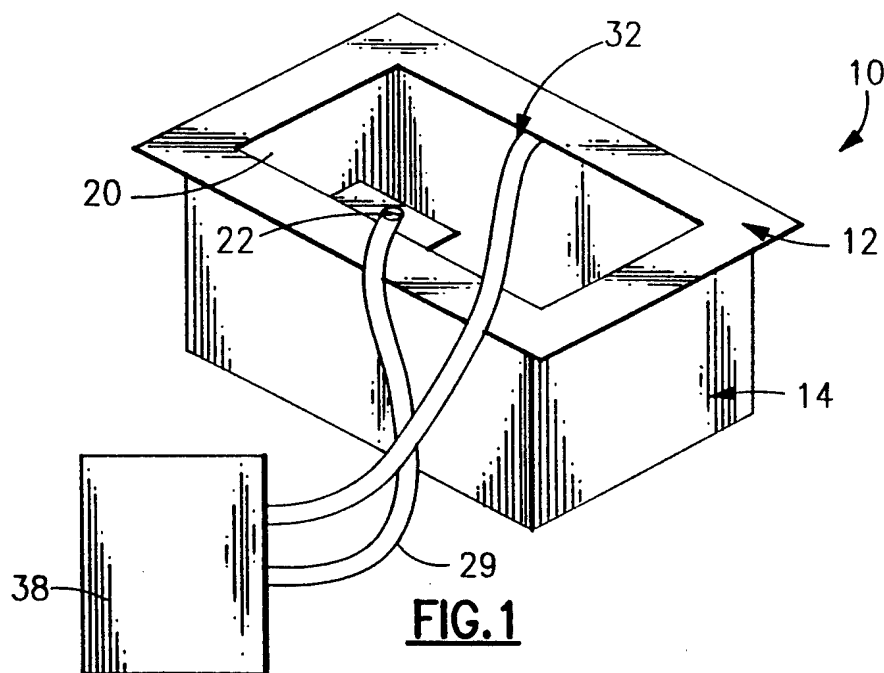
8 (a) said mesh has a grid-like configuration;

9 (b) said circulation of said fluid is
10 accomplished, at least in part, by directing said fluid
11 through at least one nozzle means, preferably by moving
12 said nozzle means in said bath, preferably wherein said
13 movement of said nozzle means is predetermined;

14 (c) further comprising adjusting formation of a
15 conventional resist pattern disposed upon said cathode so
16 as to aid said at least one mask in establishing
17 substantially uniform electroplate ion transfer to said
18 cathode; and

19 (d) further comprising adjusting formation of a
20 conventional resist pattern disposed upon said cathode so
21 as to aid said at least one mask in establishing
22 substantially uniform electroplate ion transfer to said
23 cathode.

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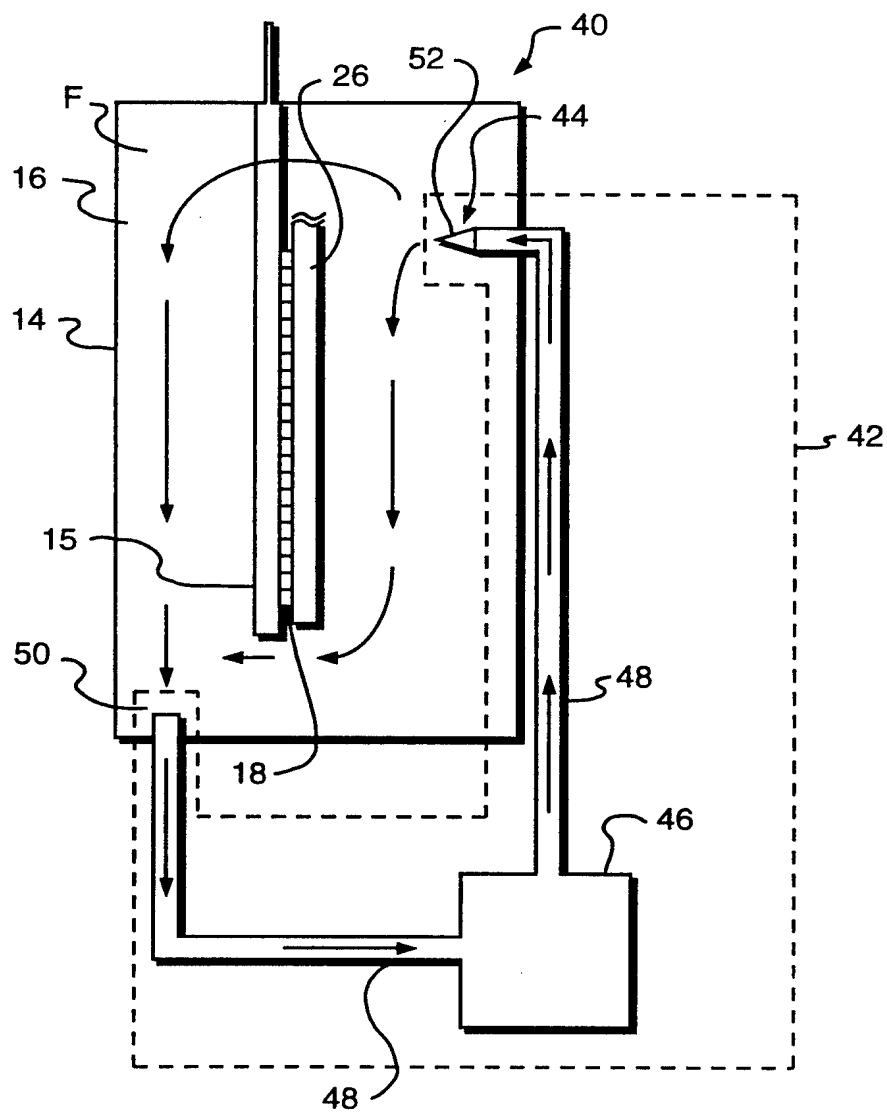


FIG. 4

SUBSTITUTE SHEET (RULE 26)

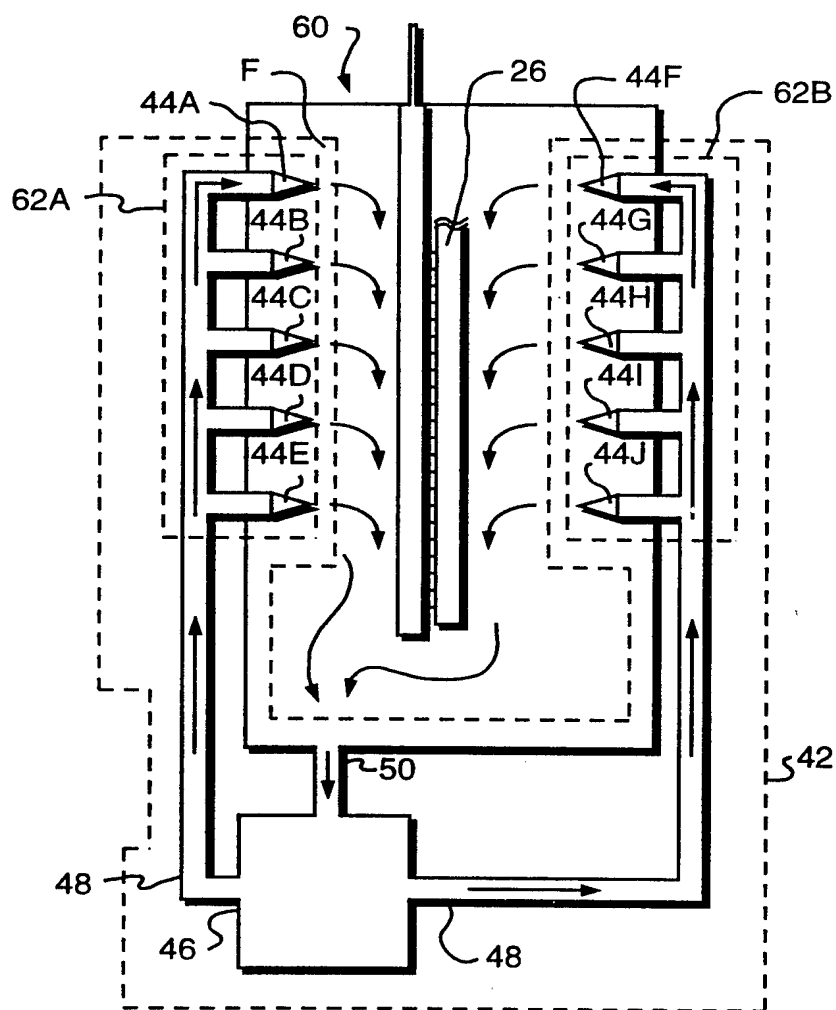


FIG. 5

SUBSTITUTE SHEET (RULE 26)

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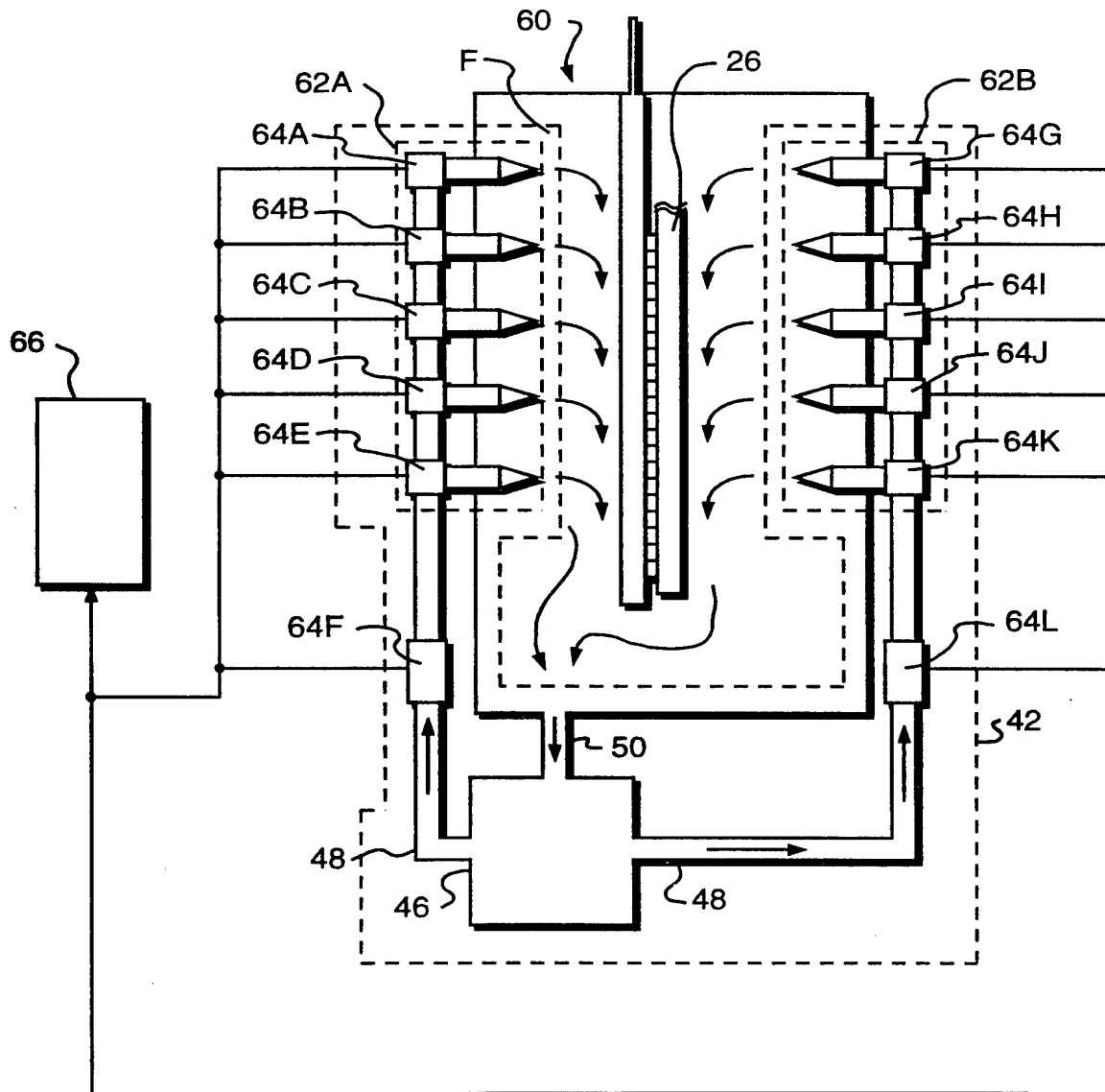


FIG. 6

SUBSTITUTE SHEET (RULE 26)

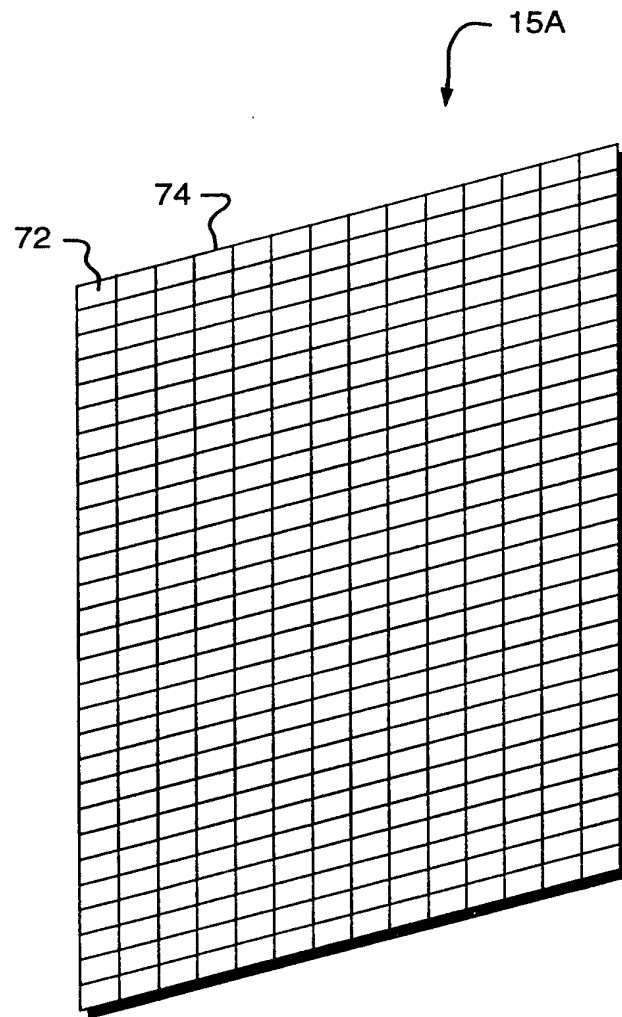


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US95/01141

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : C25D 5/00, 5/02, 17/12

US CL : 204/224R; 205/96

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 204/224R, 237; 205/96, 118, 125, 126, 135

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

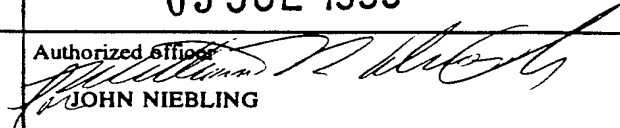
circuit board or printed circuit, mesh anode, current distribution

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,008,892 (OWEN) 14 November 1961, column 2, lines 1-19, figures 1-3.	1, 2, 5, 6
Y	US, A, 3,503,856 (BLACKMORE) 31 March 1970, column 2, lines 59-64, figures 1 and 2.	1-8
Y	US, A, 3,835,017 (MENTONE ET AL) 10 September 1974, column 3, lines 2-8, figure 2.	1-8
A	US, A, 3,962,047 (WAGNER) 08 June 1976.	1-8
X	US, A, 4,220,506 (SKURKISS ET AL) 02 September 1980, column 3, lines 20-26, figures 1 and 3.	3, 4, 7, 8
X	US, A, 4,394,241 (SCANLON) 19 July 1983, column 4, lines 8-60, figures 3 and 4.	3, 4, 7, 8

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	
A document defining the general state of the art which is not considered to be of particular relevance	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	*Z* document member of the same patent family

Date of the actual completion of the international search 12 JUNE 1995	Date of mailing of the international search report 05 JUL 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer  JOHN NIEBLING Telephone No. (703) 308-3325

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/01141

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,430,166 (CARTER) 07 February 1984, column 5, lines 46-57, figures 2, 6, 7 and 8.	1, 2, 5, 6
A	US, A, 4,534,832 (DOIRON, JR.) 13 August 1985.	1-8
A	US, A, 4,933,061 (KULKARNI ET AL) 12 June 1990.	1-8